International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 08 | Aug-2021 ISSN: 2582-3930

A comparative analysis of the population and heavy metal accumulation properties in *Chrysothrix candelaris and Pyxine cocoes* in different areas in Ernakulam district, Kerala,India

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Abstract –Lichen is an association of fungus and an alga in which two organisms are so intertwined as to form a single thallus. They colonize the natural substrata, such as bark, wood, rock soil, leaf surface, and shells and hard surfaces of living animals. The potential of these lichens is yet to be assessed and only a limited research is carried out and that too regarding the usage of the lichens as a bio indicator of air pollution has not yet been noted completely. In the present study, two common species of lichens, *Chrysothrix candelaris and Pyxine cocoes,* present in *Cocos nucifera*, has been selected as indicator species of air pollution in Kochi city. The selected diverse study areas, Vyttila and Eloor, depict the exact nature of the area. The study has been evaluated with secondary data of wind pattern and direction, temperature, rainfall and pollution status of Kochi city. The heavy metal accumulation in selected species of lichens, *Chrysothrix candelaris and Pyxine cocoes* has been studied. Finally a comparison of data obtained from study areas has also been worked out

***Key Words*:** Lichen, bio-indicators, heavy metal accumulation

1.INTRODUCTION

Lichens are an integral part of the ecosystem and any disruption in their communities affects other organisms which are dependent on them for food and roosting. They are the critical component of food web and food chains from microbes to human beings. Linnaeus (1753) published that lichens comprises of 80 species under Cryptogrammic-Algae in Species Plantarum. In India so far 2000 species have been reported from 5% of the total land area surveyed (Awasthi, 1989; Singh.V, 1996) and this figure tend to increase considerably upon surveying new localities for lichen wealth. Lichens are able to grow in different climatic conditions and equally diverse substrata. They require moisture, light, unpolluted air and undisturbed substratum for its optimum growth. The studies on the lichen flora of Kerala consist of 429 species out of which 180 are micro lichens and 248 macro lichens (Kumar and Sequiera, 1999). Lichens are extremely sensitive to environmental stress, especially concerning atmospheric pollution, eutrophication and climate change. Unlike higher plants, lichens have no cuticle and pollutants can readily penetrate to fungal and algal cells. Lichen diversity is an excellent indicator of pollution by phototoxic gaseous substances. Lichen respond faster to the deterioration in air quality and can re-colonize urban and industrial environments as a consequence of improved conditions. Extensive work has been done in temperate Europe and America for assessing the usefulness of lichens as bio indicators of atmospheric pollution. Many of the studies focus on the chemical content of lichens to determine the variability of few selected elements or chemical species in a given population through time or space. The use of lichens and bryophytes as monitors of chemical contaminants including metals, sulphur, fluoride, radionuclides and organic pollutants have been reviewed by Burton (1986). Other reviews which focuses on lichens as indicators of metal pollution have been done by James (1973), Nieboer (1981) and Martin and Coughtrey (1988). Most of the studies are focused on determining elemental baselines or examining temporal trends with respect to pollution status. The objective of the study is to compare the population and heavy metal accumulation in two species of lichens, *Chrysothrix candelaris and Pyxine cocoes* in both residential and industrial areas of Ernakulam district.

1.1. Study Area

Kochi is the second largest city in Kerala located on the west of Indian coastal areas. The river Periyar joins the Arabian Sea, after passing through this city. The city comprises diverse zones such as industrial, residential, coastal and agricultural zones. It is heavily populated and economically developed. Urbanisation is taking place at a faster rate in the area. Human activities like degradation of land, leading to reduction of natural vegetated areas, changes in land use pattern and increasing level of air pollution like SO_2 , heavy metals and radionuclide and their by-products , in Kochi area is making up life in the area to be unmanageable. In areas like Eloor, Irumpanam etc where the major industries like FACT, IRE, and KRL etc are located, the lichen diversity is at a declining state . A study dealing with the declining species of lichens relating to the air pollution in these areas has to be worked out. Two zones of the city, Eloor and Vyttila are the two sites selected for the study shown in Fig.1. In Eloor area, the western and eastern side of the factory about 2km on both the sides of the Eloor junction has been selected for the study. The western side, The Periyar River flows towards the Arabian sea. On the eastern side factories like TCC, FACT, etc are located. The westward direction is a vegetated area as Periyar River flows through this side and the eastward direction is a dry area with some vegetation near the residential area near to the factory. The western side contains high moisture content and also influenced by high wind velocity and humidity. The pollution status of the area has been compared with that of Vyttila, which is a residential zone with many buildings schools, temples hotels, etc with NH-17 passing through this area. This is wetland zone, which was recently filled and converted to residential area. Vegetation is much higher compared to Eloor. Vyttila is also on the path of urbanisation with many developmental activities being sprouted up in the area

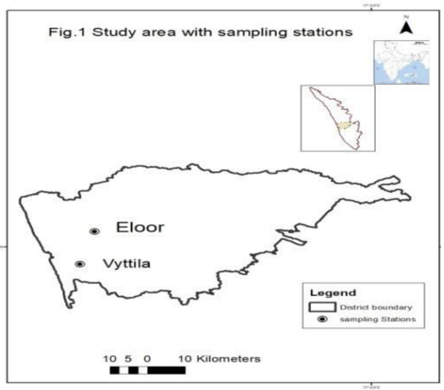


Fig.1 Study area with sampling stations

1.2. Methodology

The study was carried out in July –August of 2003. The sample tree selected *Cocos nucifera* by listing out the common tree species above height of 15ft , GBH above 30cm and highest in number . The major factors determining the distribution like height, diameter (GBH) and the distance from the source of pollution were noted for the selected tree species. The distribution pattern of two different species of lichens *Chrysothrix candelaris and Pyxine cocoes,* in *Cocos nucifera* was noted for the two study sites. The sample of *Chrysothrix candelaris and Pyxine cocoes* were collected from *Cocos nucifera* and the chemical spot test such as K,C, KC and P test were done according to Galun and Ilan (1998) for identifying the species. The greenish yellow coloration for the K test was for *Chrysothrix candelaris.* These were further identified with the help of hand lens and microscope using identification key of Awasthi (2000). A quadrat of size 20x 20 cm was laid on the four sides of the sample tree. The colony number on the four sides of the two lichen species at a height of 100cm from the ground was noted. The different meteorological factors like rainfall, temperature and wind pattern and the air pollution status during the study period were collected from Indian Meteorological Department and Kerala State Pollution Control Board. A wind rose of Kochi city was drawn from the data collected. The heavy metal accumulation in the two species of lichens was analysed using Atomic absorption spectrophotometer.

2. RESULT AND DISCUSSION

Pyxine cocoes has a foliose thallus, apprised, sub orbicular, white, pale grey, lobes narrow, radiating, rhizinate on lower surface, photobiont a green algae, medulla usually pigmented, apothecia laminal, epithelium K+ purple and the ascospores are two celled, with thick walls. *Pyxine* is also noticed on the surface of rocks, often called sexicolous, as the chemical composition and the physical structure of rocks or boulders influence it. It is found growing on rough bark, apparently due to the fact that the crevices in rough bark allow an easy foot holds and also provide moisture. Pyxifer in which is used in medicines is derived from this species.

Chrysothrix candelaris has a corticolous thallus, leprose, 0.01-0.2mm in diameter, yellowish green when dry and wet. The thallus is also homiomerous, i.e. the thallus whose tissues are not differentiated into medulla and photobiont layers, the fungal hyphae and the photobiont cells are intermixed and regularly distributed throughout the thallus. Thallus is K- and ascomata is absent in this species. The texture and age of the bark is important for the growth of corticolous lichen flora. *Chrysothrix candelaris* is widely distributed in the study area, although few in number. *Chrysothrix candelaris*, which is a crustose, lichen growing on the surface of the bark. It is called as epiphloedal. This species is authentic source of Calycin.

The colony number of lichen species *Chrysothrix candelaris* and *Pyxine cocoes*, present on the *Cocos nucifera* has been listed on Table 1.(a) and (b). In the Eloor region, the dominant species is *Chrysothrix candelaris*, which is able to tolerate dry condition with higher temperature at a small level. The dry condition is not favourable condition for the excellent growth of this species. The colony number of this species on both the sides i.e. eastward and westward direction shows the difference in their adaptability to unfavourable condition, in the eastern side colony number of *Chrysothrix candelaris* is minimum. This species is not found at the centre, where FACT and TCC are located. This may be due to higher atmospheric temperature due to polluted air emitted from the factories. In the eastern

Volume: 05 Issue: 08 | Aug-2021ISSN: 2582-3930

side also, where there is a shadowy region, *Chrysothrix candelaris* shows its normal growth. *Pyxine* species is more prominent in the western side where the river flows. This may be due to the moisture content in the wind, which makes the growth more favourable. *Pyxine cocoes* grows only in favourable condition. This species is also found to be present in few numbers in the area where small rivulet of the Periyar River passes (Table 1.a). The colony number of *Chrysothrix candelaris* is minimum near the factory, at Eloor. Colony number of *Pyxine cocoes* near the factory is scanty near the factory compared to *Chrysothrix candelaris* but it showing maximum growth in the ferry area. *Chrysothrix candelaris* and *Pyxine cocoes* are equally present in the riverside of the sampling site. The direction of growth of the two species is towards the sunlight, for the photosynthetic activity of the photobiont. Optimum temperature and wind with moisture content is the favourable growing media for the lichen species.

Table.1. (a) Distribution of Lichen species present on selected *Cocos nucifera* in Eloor

Cocos No.	Lichen sp	Colony number				Ht of cocos (ft)	GBH	Factory distance(km)
		North	East	South	West			
1	*Chrysothrix candelaris*	1-2	2-5	Nil	Nil	32	78	1.25 east
2	*Chrysothrix candelaris*	1-2	3-4	Nil	Nil	20	75	1.23east
3	*Chrysothrix candelaris*	1-3	1-9	1-2	1-2	25	80	1.22 east
4	*Chrysothrix candelaris*	50-60	50-60	Nil	Scanty	30	82	1.2 east
	Pyxine cocoes	Nil	1	Nil	Nil			
5	*Chrysothrix candelaris*	20-30	15-20	10-15	20-25	32	80	1.2 east
6	*Chrysothrix candelaris*	Scanty	1-2	1-2	Scanty	32	85	1 east
7	*Chrysothrix candelaris*	Scanty	1-2	1-2	Scanty	35	80	1 east
8	*Chrysothrix candelaris*	Nil	1-2	Scanty	5-8	40	83	0.98 east
9	*Chrysothrix candelaris*	Scanty	scanty	1-2	scanty	30	45	0.95 east
10	*Chrysothrix candelaris*	2-5	1-5	scanty	scanty	40	85	0.92 east
11	*Chrysothrix candelaris*	1-2	1-2	scanty	2-3	15	80	0.92 east
12	*Chrysothrix candelaris*	scanty	scanty	1-2	Nil	22	80	0.88 east
13	*Chrysothrix candelaris*	3-5	scanty	scanty	scanty	20	87	0.86 east
14	*Chrysothrix candelaris*	scanty	50-60	Extended	scanty	25	88	0.85 east
15	*Chrysothrix candelaris*	1-2	Nil	Nil	scanty	25	84	0.75 east
16	*Chrysothrix candelaris*	Nil	1-2	Nil	Nil	15	82	0.1 east
17	*Chrysothrix candelaris*	1-2	Nil	Nil	Nil	20	90	0.25 west
18	*Chrysothrix candelaris*	Nil	Nil	Nil	Nil	20	89	0.25 west
19	*Chrysothrix candelaris*	1-2	Nil	Nil	Nil	26	80	0.38 west
20	*Chrysothrix candelaris*	Nil	scanty	scanty	1-5	25	78	0.55 west
21	*Pyxine cocoes*	3	Nil	Nil	Nil	22	70	0,75 west
	Chrysothrix candelaris	5	scanty	1-2	scanty			
22	*Chrysothrix candelaris*	scanty	5-10	Nil	scanty	25	90	0.84 west
23	*Chrysothrix candelaris*	10-15	Nil	scanty	4-5	23	110	0.88 west
24	*Chrysothrix candelaris*	8-10	2-3	scanty	Nil	22	118	0.95 west
25	*Chrysothrix candelaris*	32	10	Nil	Nil	23	115	0.98 west
26	*Pyxine cocoes*	60-70	scanty	30-40	60-70	20	120	1.0 west
27	*Pyxine cocoes*	Nil	Nil	60-70	50-60	20	98	1.2 west
	Chrysothrix candelaris	Nil	Nil	40-60	10-15			
28	*Pyxine cocoes*	Nil	Nil	40-45	35-40	20	80	1.3 west
	Chrysothrix candelaris	Nil	Nil	20-25	20-25			
29	*Chrysothrix candelaris*	35-40	30-35	5-10	50-60	16	95	1.35 west
30	*Chrysothrix candelaris*	25-30	45-50	50-60	10-15	32	75	1.5 west

Table.1(b). Distribution of Lichen species present on selected *Cocos nucifera* in Vyttila

Cocos no.	Lichen sp	Colony number				Ht of Cocos (ft)	GBH
		North	East	South	West		
1	*Pyxine Cocoes*	20-25	60-65	65-70	5-10	15	80
	Chrysothrix candelaris	55-60	30-35	30-35	30-35		
2	*Pyxine Cocoes*	20-30	30-35	30-35	30-35	20	75
	Chrysothrix candelaris	15-30	20-25	20-25	20-25		
3	*Pyxine cocoes*	5-10	40-45	10-15	45-50	20	85
	Chrysothrix candelaris	10-15	20-25	20-25	20-25		
4	*Pyxine cocoes*	5-10	20-25	20-25	20-25	15	84
	Chrysothrix candelaris	10-15	15-20	15-20	10-15		
5	*Pyxine cocoes*	10-15	60-70	30-40	5-10	20	86
	Chrysothrix candelaris	20-25	30-35	30-35	40-50		
6	*Pyxine cocoes*	30-40	50-55	50-55	15-20	20	85
	Chrysothrix candelaris	25-30	20-25	20-25	40-50		
7	*Pyxine cocoes*	50-60	40-50	10-15	5-10	15	80
	Chrysothrix candelaris	20-25	20-25	20-30	20-30		
8	*Pyxine cocoes*	1-5	40-50	70-80	5-10	25	88
	Chrysothrix candelaris	10-20	20-30	30-35	20-25		
9	*Pyxine cocoes*	1-2	Nil	1-2	10-15	20	36
	Chrysothrix candelaris	5-6	Nil	20-25	40-50		
10	*Pyxine cocoes*	30-35	30-35	10-15	5-10	20	90
	Chrysothrix candelaris	30-40	20-30	15-20	30-40		
11	*Pyxine cocoes*	Nil	5-10	2-4	Nil	20	85
	Chrysothrix candelaris	50-60	30-35	30-35	50-60		
12	*Pyxine cocoes*	50-60	10-15	20-30	Nil	15	82
	Chrysothrix candelaris	40-50	30-35	50-60	60-90		

Vyttila, being a moderately vegetated area, shows the diversity of both *Chrysothrix candelaris* and *Pyxine cocoes* to be in equal proportion.. As this a moisturized area, the two lichen species shows a diverse and significant growth (Table 1.b). Heavy growth of *Pyxine cocoes* is noticed in the direction where humid wind pattern is present but *Chrysothrix candelaris* show minimal growth in that direction. The direction at which sunlight falls is the favourable condition for the maximum growth of *Chrysothrix candelaris*. The area near the school compound where a wet condition is noticed has the growth of *Pyxine cocoes* at a greater level. The coconut plantation in the area can be sited as a nursery for lichens with the moderate temperature for the optimum growth of lichens.

Lichens occur in a wide variety of habitat exposed to extremes of temperature, radiation, humidity or desiccation from hot deserts to cold Artic. The meteorological factors determine the presence or absence of lichen species in the area, as this play an important role in the ecology of lichens. The external factors responsible for the optimum growth of lichens are consistent availability of requisite water, sunlight, moderate cold climate, unpolluted atmosphere, wind current and an absence of biotic interference. The lichen is very sensitive to environmental changes. The changes at the local level such as land use pattern, pollution, etc may the pioneer reason for the decrease in the lichen species. Kochi city which is growing rapidly like other metropolitan city like Mumbai, Mangalore etc, is heavily populated and economically developed. Some of the areas like Vyttila where the vegetation is noticed is natural refuge to lichens like all other organisms.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 08 | Aug-2021 ISSN: 2582-3930

The meteorological data obtained from Indian Meteorological Department is shown in Table 2. A moderate to cold climate with average of 20^0- 25^0 Celsius of temperature is favourable and therefore the lichen growth, their variety, particularly of macro lichens, abounds in the temperate regions of the world. The average temperature during the sampling period was about 23^0 - 30^0 Celsius, which is a moderate temperature for the growth of lichens. *Chrysothrix candelaris* is able to tolerate a higher temperature, so it is founded in the area nearby to the factory. The colony number of this species is found to be very less in Eloor compared to Vyttila.

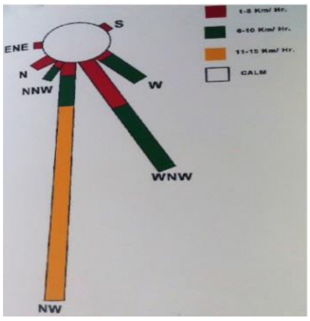
Table.2. Average temperature and rainfall in July-August 2003 of Kochi city

Month	Period	Temperature (°C)	Rainfall (mm)
July	1st week	23.6-29.1	018.6
July	2nd week	23.6-30	017.6
July	3rd week	23.7-28.8	030.2
July	4th week	24.3-27.5	008.4
July-August	5th week	24.6-30.9	007.2
August	1st week	24.8-30.7	012.2
August	2nd week	24.6-30.2	021.4
August	3rd week	23.8-29.1	022.1
August	4th week	24.3-29.4	011.5

Source: Indian Meteorological Department

A normal wind pattern is essential for the proper lichen growth. Fig.2. depicts the wind pattern of the study area in the graphical manner as wind rose. Wind currents of high velocity are liable to damage the thalli unless adapted to withstand them. Crustose and horizontally, growing foliose thalli affected by high wind currents, but erect and pendulous fruticose forms are liable to be damaged or broke apart unless suitably adapted. The *Chrysothrix candelaris*, crustose lichen and horizontally growing *Pyxine cocoes* are not much affected by wind currents. The Eloor area showing humid winds in the riverside shows higher growth to *Pyxine cocoes*. *Chrysothrix candelaris* even though grows in such a climate, a moderately humid condition with less wind velocity, is favourable condition. A certain period of time is required for the establishment of the lichen thallus on the substratum, and therefore it is essential that the substratum remains undisturbed for a period. Weber (1967) has discussed the role of climate and substratum in effecting morphological variations in the thallus of several crustose and saxicolous lichens. Rainfall is also an important factor for the growth of lichen species on the species on the substratum. A moderate rainfall with a low velocity which brings wet nature to the substratum is suitable for the growth of *Pyxine cocoes*. *Chrysothrix candelaris* usually prefer an atmosphere with low moisture content. A period with moderate rainfall with less wind currents was selected for the sampling period. The slightly vegetated area at Eloor is able to retain the moisture content leading to moderate growth of *Chrysothrix candelaris* near by the factory.

Figure.2. Wind rose of the study area



Lichens are very sensitive to air pollution and can accumulate toxic substances from the environment in their thalli. They are recognised as valuable bio monitors of atmospheric quality. The air pollution can be measured by the type of lichens in the area. They are sensitive to pollutants like SO_2, NO_X, ammonia and other gases. These pollutants decrease respiration, membrane permeability increases in the lichens and as a result the major ions present in them is lost, photosynthesis is decreased and many ultra structural changes take place. The photobiont or the algal partner is first effected by SO_2 causing the bleaching of chlorophyll-a and leading to cessation of photosynthesis followed by the degeneration and death of lichens. Ammonia which gives a nauseating effect to human beings is also harmful for lichens as it causes the species to disappear, due to the colour change and increased plasmolysis. The changes in lichens due to air pollution is mainly membrane leakage, accumulation of toxic metals and possible changes in spectral reflectance, lichen cover, morphology, community, structure and reproduction. The air pollution status of Eloor and Vyttila is shown in Table 3 (a and b). An industrial area like Eloor shows higher level of SO_2, NO_X, and ammonia denoting the scanty presence of lichen. *Chrysothrix candelaris* is able to tolerate the pollutants at a lower level showing its presence in the factory area in Eloor. The growth of *Pyxine cocoes* is noticed only in the undisturbed site about 1.5 to 2km from the factory. Vyttila is showing a favourable site for the growth of the two lichen species. The SO_2, NO_X, and ammonia are at very low level in Vyttila, as a result the lichen diversity and distribution pattern is wider in this place then Eloor.

Table 3(a). Showing the air pollution status of Eloor

Month	Period	SO_2 (μgm/m³)	NO_X (μgm/m³)	NH_3 (μgm/m³)
July	1st week	94.7	7.5	65.9
July	2nd week	47.3	5.12	74.6
July	3rd week	75.4	11.9	80.5
July	4th week	70.7	16.5	73.1
July-August	5th week	45.6	15.8	76.9
August	1st week	58.8	17.5	68.9
August	2nd week	46.4	11.5	125.9
August	3rd week	34.4	6.88	145.0
August	4th week	69.3	11.9	64.9

Source: Kerala State Pollution Control Board, Kochi

Table 3(b). Showing the air pollution status of Vyttila

Month	Period	SO_2 (μgm/m³)	NO_x (μgm/m³)	NH_3 (μgm/m³)
July	1st week	1.87	10.7	32.6
July	2nd week	1.56	4.95	62.7
July	3rd week	3.0	5.4	28.4
July	4th week	1.55	6.95	23.1
July-August	5th week	0.38	8.5	41.9
August	1st week	0.49	10.3	25.8
August	2nd week	0.42	7.5	105.0
August	3rd week	0.8	8.5	37.65
August	4th week	0.8	10.3	48.7

Source: Kerala State Pollution Control Board, Kochi

Heavy metal acts as the major pollutant. Lichens acts as accumulators of heavy metals and radionuclide. Heavy metal accumulation noticed in both the study areas is shown in Table 4 a and b. The cadmium, lead, and mercury is very low in both the areas. Zinc at Eloor is higher compared Vyttila. The iron content in two areas is almost equal for the two study areas. Analysing the interdependency of the different metals, showed a very high correlation between zinc and copper ($P<0.001$) indicating that as Zinc in the lichen sample increases the copper also increases significantly. There is a significantly positive correlation between cadmium-lead ($P<0.001$) and zinc-iron ($P<0.005$). In other metals the coefficient of correlation is not significant at 5% level. A comparative study of heavy metals accumulated in two species showed greater in *Chrysothrix candelaris*. Iron accumulated in this species at Vyttila is about 12.5mg/g which shows that this species has the capacity to accumulate iron at higher levels. The amount of heavy metals like cadmium, lead and copper is higher in Eloor due to industrial pollution. The heavy metals accumulated denote the capacity of the lichens to accumulate the pollutants from the environment, denoting it to be a purifier of the atmosphere.

3. CONCLUSION

Lichens present in the selected *Cocos nucifera* i.e. foliose lichen like Pyxine *cocoes* and crustose lichen like *Chrysothrix candelaris* tend to show a different growth pattern in the two study areas. *Pyxine cocoes* is showing its presence in the areas where moisture content is at higher level. It is very sensitive to air pollution and any other climatic factors, such as wind speed, rainfall etc. This species can be taken as the best indicator of air pollution and extreme climatic changes. A reliable and useful bio indicator is those which should be expected to occur in area where it is not polluted, but still occur in adjacent areas. These should occur in open habitats, showing range of sensitiveness and are easily recognised in the field. The decrease of lichen species in Eloor is an example of destruction due to industrialization. The use of lichens as an indicator has an advantage of relatively of low cost. The usage of lichen in denoting the pollution status of an area is noted to be as a future perspective. Even though eminent scientist has conducted many studies, better monitoring techniques for atmospheric pollution have not been evolved. An integrated approach in which bio indicators, bio accumulators, and chemical monitoring techniques are to be used jointly for the appropriate solution for monitoring the air pollution.

ACKNOWLEDGEMENT

I extend my graduate to Dr.Satheesh, Supervising Guide and Reader, SES and K.S. Vijayakumar, Senior Scientist, KSPCB, for providing me valuable advice in preparation of this report.

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